# Solar heating Panels

1- Flat-plate collectors are special type of heat-exchangers

2.Energy is transferred to fluid from a distant source of radiant energy

3-Incident solar radiations is not more than 1100 W/m2and is also variable

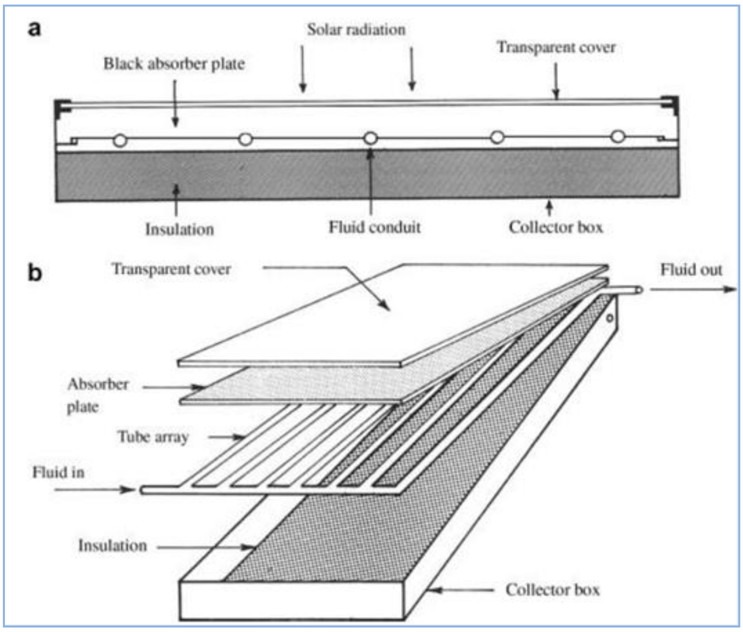
4.Designed for applications requiring energy delivery up to 100°C above ambient temperature.

## Design of Flat-Plate Solar Collectors and Solar Energy Heating Systems

Simple liquid-type flat plate collector is illustrated in Figure, it consists of
1- a black absorber plate whose absorptivity for solar radiation is near unity.
2- A selective absorber coating of low thermal emissivity is deposited on the plate.
3- The plate is fitted with tubes or canals so that
a transfer liquid can extract the heat produced in the Plate when solar energy is absorbed. For air-type collectors, forced ducts are affixed to the plate and air is circulated either by or natural convection. The plate is placed in an airtight insulated Container and covered with a glazing. Back and side thermal losses are usually negligible when compared with front losses through the glazing.

The basic parameter to consider is the **collector thermal efficiency**. **This is defined as the ratio of the useful energy delivered to the energy incident on the collector aperture**. The incident solar flux consists of direct and diffuse radiation. While flat-plate collectors can collect both, concentrating collectors can utilize direct radiation only if the concentration ratio is greater than (10).

Heating panels can be classified as either **active** or **passive** according to whether a pump (or a blower) or natural convection is used to circulate the fluid. We address ourselves to active,




a) typical flat plate collector showing transfer pipes (dashed lines) under the absorber plate.
(b) A cross-sectional view of the same flat plate.

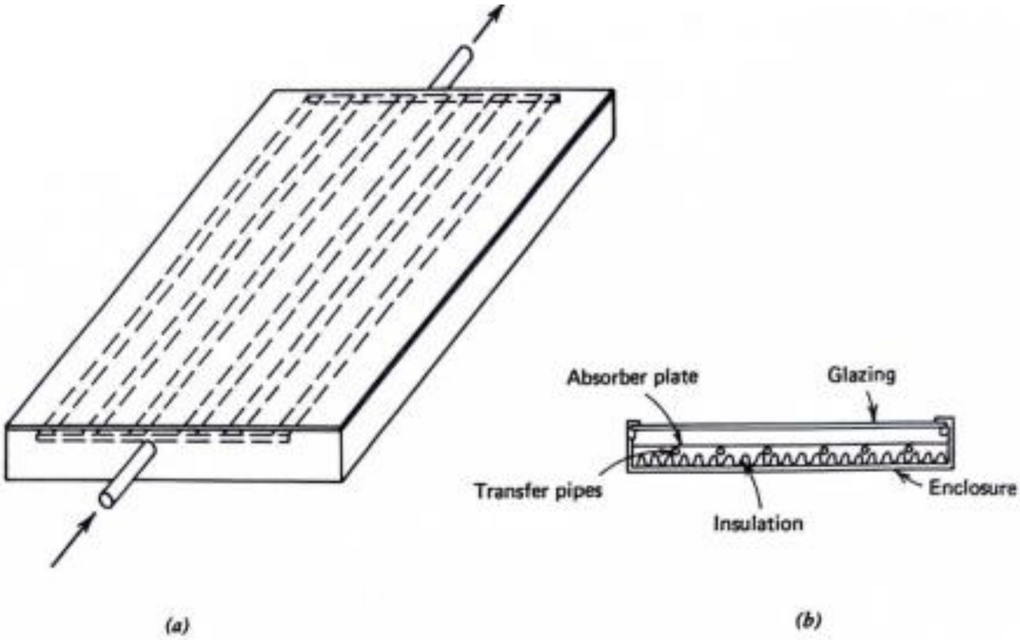



FIGURE 1 (a) *A typical flat plate collector showing transfer pipes (dashed lines) under the absorber plate.* (b) *A cross-sectional view of the same flat plate.*

losses through the glazing. Heating panels can be classified as either active or passive according to whether a pump (or a blower) or natural convection is used to circulate the fluid. We address ourselves to active, liquid-type, flat plates.

The overall efficiency of a solar heating panel is defined as

$$\boxed{\eta = \frac{J_c}{F_{inc}}} \qquad 1$$

where

$J_c$ = heating power collected/collector area

and

$F_{inc}$ = solar flux intercepted by the collector

It is convenient to separate the efficiency in Equation 1 into two parts—one that characterizes optical performance and a second that describes thermal effectiveness. We write Equation 1 as

$$\boxed{\eta = \frac{J_c}{F_{inc}} = \frac{F_{abs}}{F_{inc}} \times \frac{J_c}{F_{abs}} = \eta_{opt} \times \eta_{thermal}} \qquad (2)$$

where

$$\eta_{opt} = \frac{F_{abs}}{F_{inc}} \qquad \text{and} \qquad \eta_{thermal} = \frac{J_c}{F_{abs}}$$

Here, $F_{abs}$ is the solar flux actually absorbed and is therefore equal to the heating power per unit area produced within the absorber plate.

The optical efficiency was shown to be given approximately by

$$\boxed{\eta_{opt} \simeq A_p \times T_g} \qquad (3)$$

where $A_p$ represented the solar absorptance of the plate and $T_g$ the transmittance of the glazing. The optical efficiency can exceed 85 percent even in a relatively unsophisticated panel, provided the angle of incidence of the direct solar radiation is not too large.

The limiting factor in most simple flat plates is the thermal efficiency, $\eta_{thermal}$. Thermal losses to the environment are significant, especially when high output temperatures are required and the panel is operating in a cold and windy environment. In this chapter we will be concerned primarily with thermal performance.

## Stagnant Performance of a Solar Heating Panel

When solar energy is incident on a heating panel and heat is not being extracted, the thermal efficiency is zero and all the heat produced by the plate is lost to the surroundings. The absorber plate reaches a uniform temperature $T_{p,s}$ called the static or *stagnation* temperature. For a collector of specific design and tilt, the stagnation temperature of the plate will be a function of both the absorbed solar flux and the ambient conditions, and we may write

$$T_{p,s} = T_{p,s}(F_{abs}, f_{amb}) \qquad (.4)$$

The label $f_{amb}$ represents all relevant ambient parameters such as air temperature, $T_a$, sky temperature, $T_{sky}$, and wind velocity. The plate temperature increases as the level of absorbed insolation, $F_{abs}$, increases and decreases as the ambient conditions become more severe (i.e., cold and windy).

To establish the relation, Equation .4, we note that under stagnant conditions—when no useful heat is extracted—the steady state is reached when the absorbed solar flux is equal to the thermal flux loss, that is,

$$\boxed{F_{abs} = J_{loss} \qquad \text{(stagnancy condition)}} \quad (\ .5)$$

If the sky temperature is approximately equal to the air temperature, the flux loss can be written

$$\boxed{J_{loss} \simeq \bar{U}_c(T_{p,s} - T_a)} \quad (\ .6)$$

where $\bar{U}_c$ is the overall coefficient for heat transfer from the absorber plate to the surroundings. If a linearized form is assumed and $\bar{U}_c$ is taken to be constant, Equations .5 and .6 can be solved as

$$\boxed{T_{p,s} - T_a \simeq \frac{F_{abs}}{\bar{U}_c}} \quad (\ .7)$$

If multiple glazings and selective absorbers are used, $\bar{U}_c$ will be small and $T_{p,s}$ will increase dramatically as the absorbed solar flux increases.

A similar relation to Equation .7 can be applied to the glazing temperature of a single-glazed collector. Because the flux transfer from the plate to the glazing and from the glazing to the surroundings must be equal to each other and each must be equal to $F_{abs}$, we have

$$T_{g,s} - T_a = \frac{F_{abs}}{\bar{U}_{g-a}} \quad (\ .8)$$

where $\bar{U}_{g-a}$ is the coefficient for transfer of heat from the glazing to the surrounding air.

The overall heat-transfer or loss coefficient is obtained using

$$\frac{1}{\bar{U}_c} = \frac{1}{\bar{U}_{p-g}} + \frac{1}{\bar{U}_{g-a}} \quad (\ 9)$$

where $\bar{U}_{p-g}$ refers to heat transfer from the plate to the glazing. For high quality, single-glazed, solar panels, we usually find that $\bar{U}_{p-g} \ll \bar{U}_{g-a}$. This means that the temperature difference between the glazing and the surrounding air is generally much smaller than the temperature difference between the plate and the glazing.

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EXAMPLE

Using Equation 7, obtain the relationship between the absorbed flux and the stagnancy temperature of the plate of a collector whose transfer coefficients are $\bar{U}_{p-g} = 10$ W/m$^2$-°C and $\bar{U}_{g-a} = 15$ W/m$^2$-°C. Take $T_a = 10$°C. Using Equation 8, also find the relationship between the glazing temperature and the absorbed flux. Repeat the analysis when a selective coating deposited on the plate reduces the plate-to-glazing coefficient to $\bar{U}_{p-g} = 5$ W/m$^2$-°C.

In the first case we have

$$\frac{1}{\bar{U}_c} = \frac{1}{10} + \frac{1}{15}$$

or

$$\bar{U}_c = 6 \text{ W/m}^2\text{-°C}$$

From Equation 7, we have

$$T_{p,s} = \frac{F_{abs}}{6} + 10 = 0.167F_{abs} + 10$$

For the glazing we have

$$T_{g,s} = \frac{F_{abs}}{15} + 10 = 0.067F_{abs} + 10$$

In the second case (i.e., the selective absorber) we have

$$\frac{1}{\bar{U}_c} = \frac{1}{5} + \frac{1}{15}$$

or

$$\bar{U}_c = 3.75 \text{ W/m}^2\text{-°C}$$

so that

$$T_{p,s} = \frac{F_{abs}}{3.75} + 10 = 0.0267F_{abs} + 10$$

For the glazing we have

$$T_{g,s} = \frac{F_{abs}}{15} + 10 = 0.067 F_{abs} + 10$$

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Note that although the stagnation temperature of the plate is increased by the selective coating, the stagnation temperature of the glazing remains unaffected. The results of the preceding example are plotted in Figure 2.

Curves of the type shown in Figure 2 are very useful in analyzing collector performance. Because the stagnation temperature represents an upper limit to the temperature that can be derived from a collector when it is operational, the plots of $(T_{p,s} - T_a)$ versus $F_{abs}$ indicate the maximum temperatures attainable for given insolation levels and ambient conditions. They also provide estimates of

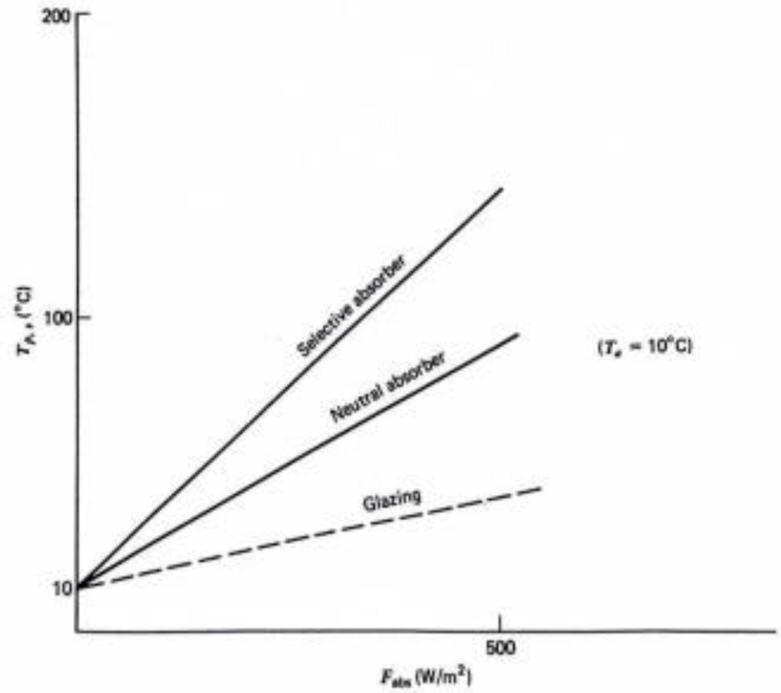


FIGURE 2 *Plots of the stagnation temperatures of an absorber plate versus absorbed solar flux. The ambient temperature is $T_a = 10°C$. The selective coating increases the plate temperature; the glazing temperature (dashed lines) is unaffected by the coating.*